

Investigation of the additive effect of nanoparticles on the hydrodynamic characteristics of drilling fluids

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Abstract. Investigations of the rheological properties of drilling fluids based on nanoparticles are carried out. The dependences of the effective viscosity and rheological parameters of fluids on the concentration, size and material of nanoparticles, and the physico-chemical properties of the model fluid are obtained. The study results of the filtration of drilling fluids with nanoparticles are obtained. Dependences of filtration characteristics of drilling fluids on concentration, size and material of nanoparticles are obtained.

1. Introduction

The drilling fluid circulating in the borehole can penetrate into cracks resulting from excessive drilling mud pressure into previously existing open cracks or into large cavities that have structural strength (such as large caverns or canals formed as a result of leaching). At present the main means of lost-circulation control is the flush of filler material in zone of loss, i.e. solid phase, which forms the colmatation zone at the boundary of the borehole - bed. The use of this method leads to a permeability decrease of the mud zone, followed by the formation of a barrier both at the flush and at the solid and colloidal phases contained in the drilling fluid. For the reservoir drilling-in the ability to penetrate the filtrate and solid particles into the reservoir pores is minimized, while optimizing the formulation of the drilling fluid, which is provided by the use of highly disperse stabilizing reagents and special colmatants [1].

At the same time, the filtration losses of the drilling fluid in the reservoir are one of the main causes of crack proliferation and the borehole instability. These processes significantly increase the costs and risks of drilling around the world. Filtration losses is the situation when the drilling fluid partially or completely flows into the reservoir through the areas called zone of loss [2].

Recently a studies have shown the effect of the use of nanoparticles additives in drilling fluids to improve their properties. Some papers have shown that composition optimizing and fillers properties in drilling fluid is a absorption prevention into permeable bed [3,4]. In others, on the contrary, nanoparticles reduce the injection rate by forming a material layer with an equal or higher ultimate strength on surface [5]. However, experiments are separated and not systemic. Results are often contradictory, so further research is needed that are carried out in this paper.

Special investigates to study filtration processes through a porous medium were carried out for a valuation of the colmatizing ability of materials. In our paper a complete research list of the properties of drilling fluids modified by nanoparticles was carried out.

2. Drilling fluids rheology

Viscosity and rheology of drilling fluids play the most important role for their application, since they depend on pressure drop during flushing-out of well, cutting transport efficiency, borehole stability and much more.

Thereby systematic studies of the adding nanoparticles effect on the viscosity and rheology of drilling fluids carried out in the paper.

Nanosuspensions are prepared on basis of model drilling fluids. Particles of silicon oxides are considered as nanoparticles. The particles concentration in solutions ranged from 0.25 to 2% by mass. The particle size is 10 and 100 nm. Powders of metal oxides were purchased from the company "New Powder Technologies", Tomsk. A standard two-step method was used to prepare the nanosuspension. The required quantity of powder is added to the fluid, after which the resulting suspension is mechanically mixed. To destroy the conglomerates of nanoparticles the suspensions are subjected to ultrasonic treatment of the Sapphire TC-10338 bath.

Clay drilling fluid on water base was used as the base fluid. The mass concentration of clay is 5%.

Rheology investigation of the created nanosuspensions was carried out by the OFITE HPHT rotational viscometer. This fully automated system is designed to determine the rheological properties of fracturing fluids, drilling fluids and oil-well cement at elevated temperatures (up to 260 °C) and pressures (up to 17MPa). The range of shear stresses is 0-4000 D/cm². Speed range: 0.01 - 600 rpm. Speed control accuracy: 0.001 rpm. Shear rate range: 0.01 - 1022 s⁻¹.

As a result the dependences of the effective viscosity and rheological parameters of these solutions on the concentration, size and material of the nanoparticles, the physical and chemical properties of the model drilling fluid was obtained (Fig. 1.2).

It is shown that with the nanoparticles addition of 2% by mass, the power model exponent of the drilling fluid varies from $n = 0.6$ to 0.25 relative to the base solution. The structural viscosity increased from $K = 0.07 \text{ Pa} \cdot \text{s}^n$ to $K = 1.3 \text{ Pa} \cdot \text{s}^n$.

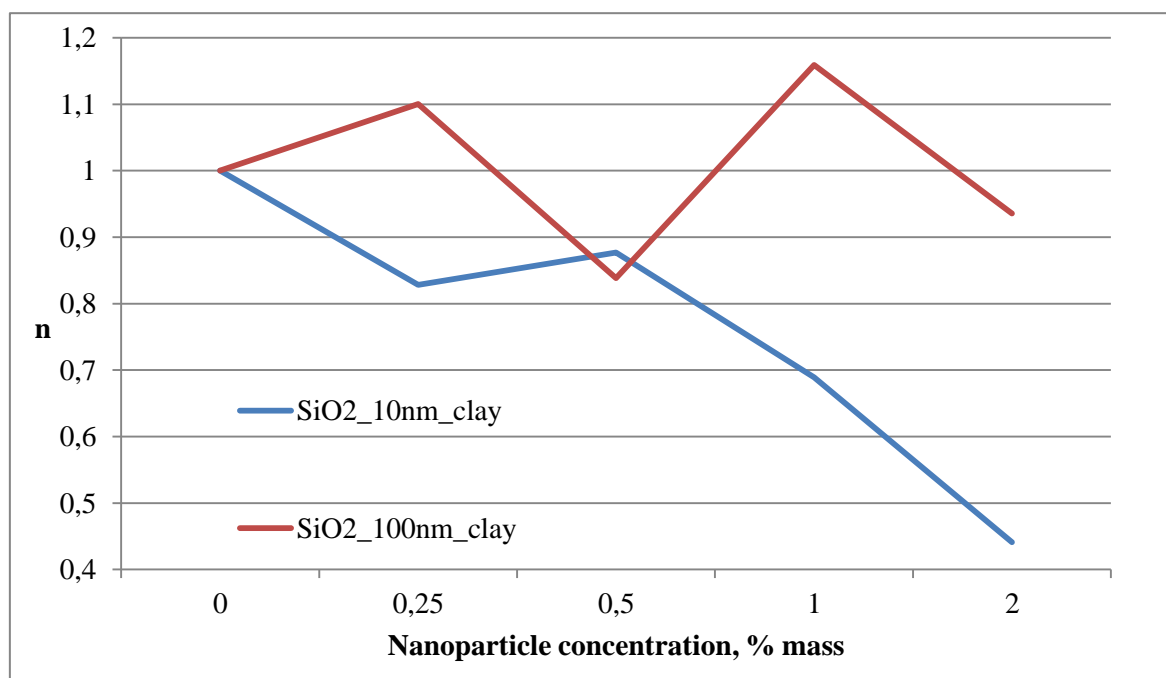


Fig.1 Dependence of power law index on the nanoparticles concentration

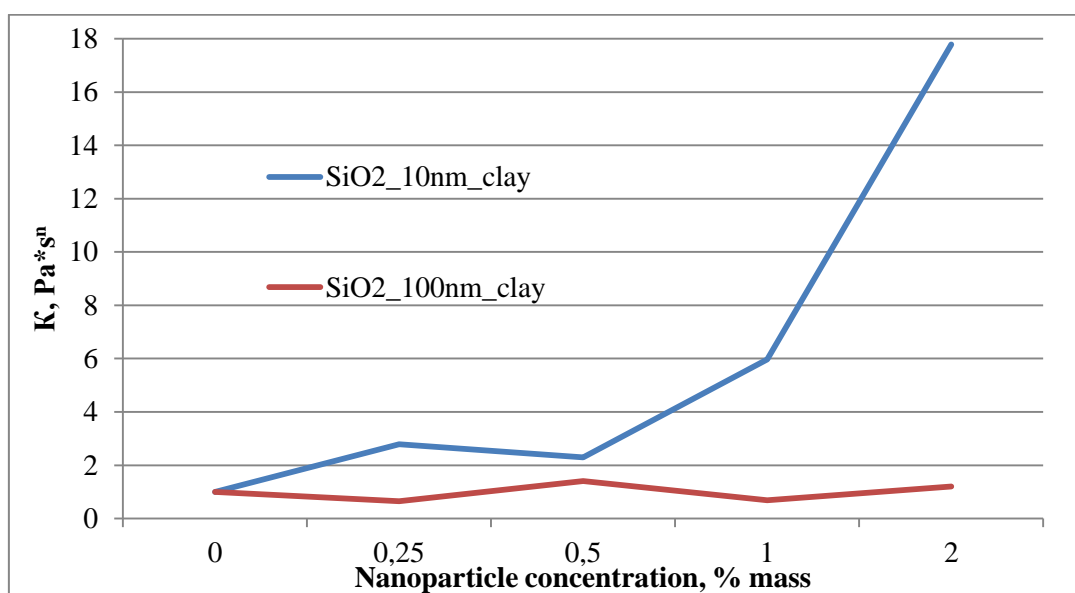


Fig.2 Dependence of consistency index on the nanoparticles concentration

3. Drilling fluids filtration

At present many studies performed on the filtration properties of drilling fluids with additives of nanoparticles [6-8]. In all these papers a significant effect of nanoparticles is noted. However, the experiments results are still contradictory: in some researchers the filtration losses decrease with the addition of nanoparticles, in others, on the contrary, ones increase. There is no clear explanation for this contradiction in the mechanisms of the influence of nanoparticles.

Thereby the filtration properties of drilling fluids with nanoparticles were systematically studied. These researches were conducted on standard paper filters (API standard). A 6-sectional press filter OFITE 140-50 was used, which has mud cells and a pressure building unit. The API standard (American Petroleum Institute) recommends filtering the solution through a filter for 30 minutes at a pressure of 7 atm. In this way the volume of percolating fluid through this filter is determined, which is called the filter loss.

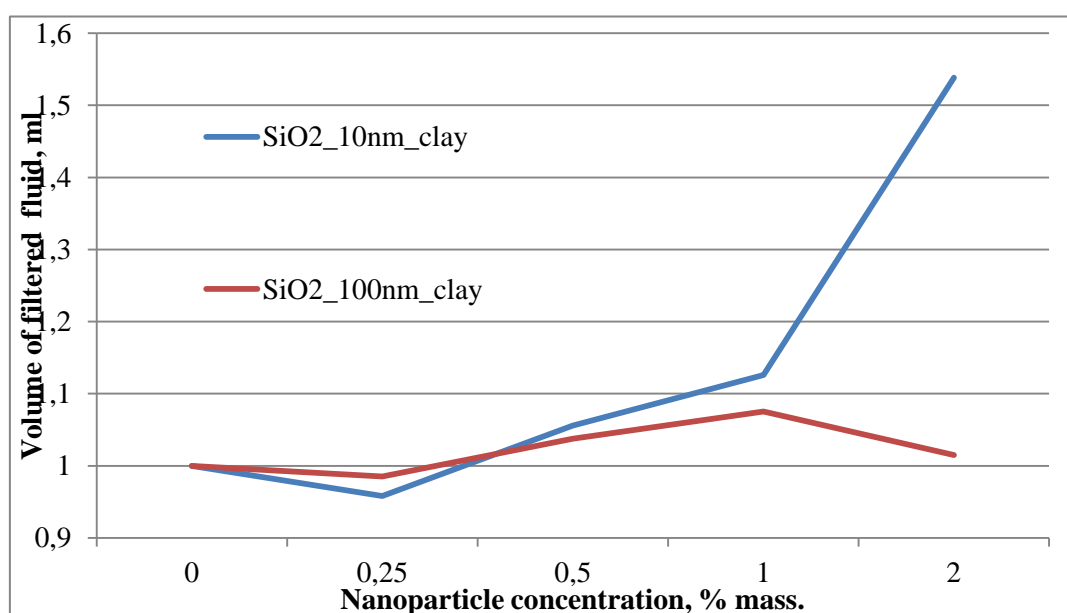


Fig.3 Filtration of water-based mud with the SiO₂ nanoparticles addition

Typical results of the experiment on the drilling fluid filtration with nanoparticles are shown in Fig. 3. It is shown that in this case the addition of nanoparticles with an average size of 10 nm leads to increase in the filtration losses by approximately 1.6 times. In addition it was shown that the filtration losses essentially depend on the size of the nanoparticles. Graph is shown the particles with an average size of 100 nm practically do not affect the filtration of drilling fluids. The dependence of the filtration properties on the particle size can be the reason for the observed divergences in different authors and requires further research.

Conclusion

The rheological and filtrational properties of drilling fluids with addition of various sizes nanoparticles are investigated. It is shown that as the concentration of nanoparticles increases, the power law index decreases, and the structural viscosity increases significantly. It was found that the nanoparticles effect on the properties of drilling fluid depends on the nanoparticles size. Influence of nanoparticles on the rheological and filtration properties of drilling fluids slackens with the increase ones. It is shown that filtering of the clay solution through the porous medium is greatly improved with the increase in the concentration of silicon oxide nanoparticles with an average particle size of 10 nm. In our opinion this is due to an improvement in the rheological properties of fluids with an increase the nanoparticles concentration. Thus, the relationship between the filtration losses and the rheology of drilling fluids with nanoparticles was established.

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